§8. Core Temperature Flattening by Formation of Stochastic Magnetic Field

Tsuchiya, H., Ida, K., Osakabe, M.,
Nagaoka, K., Nagayama, Y.

It is a quite important issue to realize the high ion temperature plasma in fusion oriented plasma devices including the Large Helical Device (LHD). The study of high ion temperature plasma in core region is related to the magnetic structure in core region, which have a large influence of plasma confinement. It has been considered that the magnetic topology is not only determined by the external coil but also plasma current [1, 2]. But the direct measurement of magnetic topology itself in plasma is not easy. We have been suggested the heat pulse propagation [3] method as a tool to measure the magnetic structure [4] in Large Helical Device (LHD). This method using the radial velocity of heat pulse can clearly indicate the stochastic field area or islands.

On LHD, the high ion temperature discharge is achieved after a carbon pellet injection into the plasma which is maintained by subsequent radial Neutral Beam Injection (NBI). At the high ion temperature discharge, the ion temperature radial profile often shows the flatting shape at the central region [5], and the flattening phenomena prevents the higher ion temperature.

The power modulation electron cyclotron heating (MECH) was applied to the plasma sustained by neutral beam injection (NBI). The frequency of MECH is 30Hz. The power deposition point of 77GHz ECH is at r_{eff} = 0.12m in fig.1. The MECH generates the heat pulse propagating outward, which is observed by ECE as fluctuation of electron temperature whose frequency is 30Hz. Fig. 1 shows the aspect of the heat propagation at ion temperature peaking discharge and flattening discharge. The peaking discharge is sustained by the co- and ctr- NBI, while the flattening discharge is sustained by only the co-NBI. The plasma current of flattening discharge is twice of current of flattening discharge. Generally the maximum amplitude point of the heat pulses corresponds to the deposition point of ECH. In peaking discharge we can see the radial peak point at $r_{\mathrm{eff}} \sim 0.13$m. It is considered that the heat pulse propagates outward radially, and the magnetic structure is nesting surfaces in the core region. The graph of delay time of heat pulse propagation, which corresponds to the propagation velocity, also shows the outward propagation in peaking discharge. In flattening discharge, there are the flattening region $r_{\mathrm{eff}} < 0.25$m in both radial amplitude profile and the radial delay time profile, even though the MECH condition is same as one of peaking discharge. These experimental results indicate that the heat pulses propagate rapidly and the magnetic structure change to stochastic state. The carbon pellet was injected to these discharges, but it is confirmed that the injection is not a trigger of stochastization.

The ion temperature flattening area $r_{\mathrm{eff}} < 0.2$m does not exactly match the stochastization area defined by heat pulse propagation analysis, as shown in fig. 2. The mechanism is not still clear, but the transport characteristic in stochastization area is worse than one of nesting magnetic structure. We have to make high ion temperature discharge scenario avoiding the formation of stochastic magnetic field in core region.

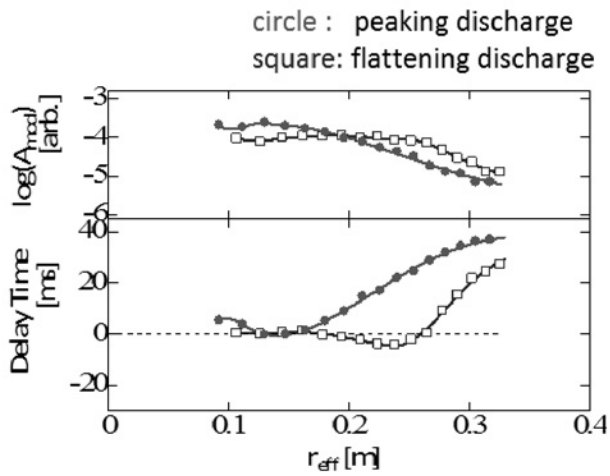

Fig.1 Aspect of the heat propagation, comparing between the ion temperature peaking discharge and flattening discharge. Up: the amplitude of heat pulse (A_{mod}) radial profile. Down: the delay time profile of the heat pulse.

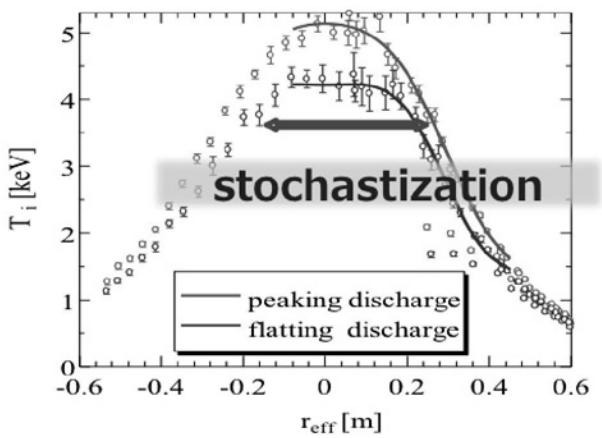

Fig.2 The radial ion temperature profiles. The stochastization area is larger than the ion temperature flattening region.

1) T.E. Evans *et al.*, Nature Phys. **2**, (2006) 419.
2) M. Hirsch *et al.*, Plasma Phys. Control. Fusion **42** (2000) A231.
3) S. Inagaki *et al.*, Phys. Rev. Lett. **92** (2004) 055002.
4) K. Ida *et al.*, N.J. Phys. **15** (2013) 013061.
5) Osakabe, M., *et al*, Annual Report of NIFS April 2010-March 2011, p14.